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Revision 0

Dashboards and Control Charts

Experiences in Improving Safety at Hanford Washington

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management
Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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Dashboards and Control Charts - Experiences in Improving Safety at Hanford Washington

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Introduction

The aim of this paper is to demonstrate the integration of safety methodology, quality tools, leadership, and teamwork at Hanford and their significant positive impact on safe performance of work. Dashboards, Leading Indicators, Control charts, Pareto Charts, Dr. W. Edward Deming's Red Bead Experiment, and Dr. Deming's System of Profound Knowledge have been the principal tools and theory of an integrated management system. Coupled with involved leadership and teamwork, they have led to significant improvements in worker safety and protection, and environmental restoration at one of the nation's largest nuclear cleanup sites.

The Hanford Site

Quality tools, leadership, and worker-supervisor teaming are playing a key role in safety and quality at what has been called the world's largest environmental cleanup project. The U.S. Department of Energy's (DOE) Hanford Site played a pivotal role in the nation's defense beginning in the 1940s when it was created as part of the Manhattan Project. The Hanford site is about 250 miles from Seattle, at the location shown in Exhibit 1. After more than 50 years of nuclear weapons production, Hanford, covering 560 square miles in southeastern Washington state, is now focused on three outcomes:

1. Restoring the Columbia River corridor for multiple uses.
2. Transitioning the central plateau to support long-term waste management.
3. Putting DOE assets to work for the future.

The current environmental cleanup mission faces challenges of overlapping technical, political, regulatory, environmental, and cultural interests. Fluor Hanford, my employer and a prime contractor for the DOE, has the ultimate responsibility for cleaning up a large portion of the site. Our emphasis has to be on safety, quality of work, controlling costs, and meeting deadlines.

Exhibit 1. The Hanford Site is located in eastern Washington.

The Voluntary Protection Program

The Department of Energy Voluntary Protection Program (DOE-VPP) promotes safety and health excellence through cooperative efforts among labor, management, and government at DOE contractor sites. DOE has also formed partnerships with other Federal agencies and the private sector for both advancing and sharing its VPP experiences and preparing for future program challenges. The safety and health of contractor and federal employees are a high priority for the Department. The DOE-VPP program is based upon the OSHA (Occupational Safety and Health Administration) Voluntary Protection Program. This broad basis allows for cooperation between government and private corporations.

The employees of Fluor Hanford are proud of their environmental cleanup progress, and the continually improving safety record. The safety and health of employees and contractors are extremely important at Fluor Hanford. Fluor has demonstrated an 84% reduction in OSHA recordable injury rate since taking over the Hanford contract in 1996. This record would not have been achieved without workers, managers, and safety professionals utilizing the tenets of the Voluntary Protection Program. These tenets are

Management Leadership
Employee Involvement

Worksite Analysis
Hazard Prevention and Control
Safety and Health Training.

Integrating Quality Tools

The use of quality tools is pervasive through the five tenets of VPP. Statistical Process Control (SPC) has been a primary tool used in Worksite Analysis and Hazard Prevention and Control. Safety and Health Training has been supported through the use of Dr. Deming's Red Bead Experiment and monthly training through the "Hanford Performance Indicator Forum." Just two years ago (May 20, 2004), the author presented the Red Bead Experiment to the Voluntary Protection Program Participant's Association Region X annual workshop. One year later, a presentation including VPP was made at the American Society for Quality's annual conference. For 2006, the presentation returns to the safety arena with this paper at ASSE. The cross-pollination between safety and quality continues.

The Red Bead Experiment was part of Dr Deming's four-day seminars that were given across the country in the 1980s. The experiment is documented in his book "The New Economics". The Red Bead Experiment has been used at the Hanford Site for a hands-on training session in how this principle works. A bucket of beads of two colors is used. Red beads are "bad." White beads are "good." The number of beads of each color remains the same through the course of the Experiment. Although the red beads are randomly mixed through the supply, we note there is always some worker who has the least red beads, and some worker with the most. Half of the workers will get worse from one try to the next, half will get better. Workers receive praise and correction depending on whether they are better or worse than their peers, or based upon comparison to their previous attempts. Numerical targets are set for reduced numbers of red beads. Cash incentives are offered for meeting targets (which never seem to be met). The Experiment is a very powerful experience. One hour with the Red Beads have transformed safety professionals (or at least started the transformation) from setting targets and following the numbers to understanding what the numbers are telling them. During the session, one can note from the audience reaction the transformation in thinking that occurs. The experience at first appears humorous, but as participants recognize the common factors with their actual work, they realize that a new method is needed for responding to data.

The Red Bead Experiment provides an initial introduction to a control chart and Statistical Process Control. Control charts allow the user to segregate random noise from signals and trends. The data for each time interval are plotted, and an average line is plotted through the middle of the data. An upper control limit is added at three standard deviations above the average and a lower control limit is added at three standard deviations below average. There are many sources of instruction for making control charts. One example is the author's Hanford Trending Primer, which may be found on the internet at http://www.hanford.gov/safety/vpp/trend.htm.

Management Leadership and Employee Involvement have been focused through the use of SPC and Pareto Chart analysis. For those that may believe the workforce cannot understand SPC, the author has definite evidence to the contrary. Pareto Charts and SPC are used routinely in safety meetings and planning sessions at Hanford. Union, management, and safety professionals have been able to extend their cooperation through the common language of quality tools.

Results

The results speak for themselves. The control chart in Exhibit 2 below shows a pattern of continual improvement. There has been an 84% reduction in OSHA recordable injuries comparing 1995 performance to present.

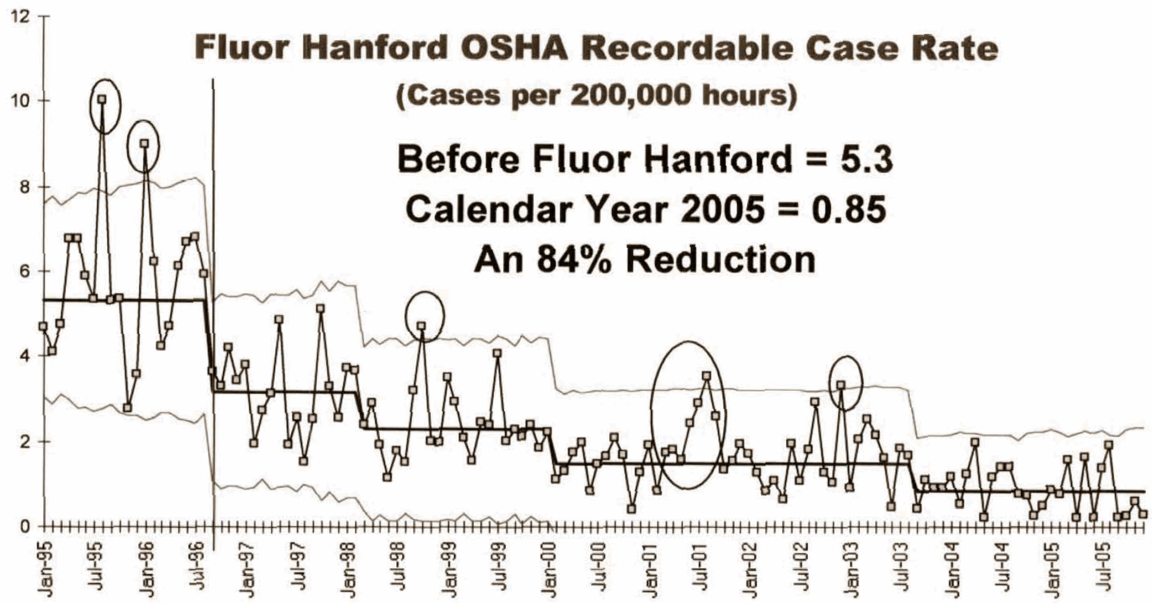

Exhibit 2. This is the control chart of the OSHA Recordable Injury Rate for Fluor Hanford's current scope of work.

Sound Theory And Knowledge

The key to this success has been the consistent application of sound management and statistical principles. Dr. Deming's System of Profound Knowledge (Deming) includes

Appreciation for a system
Knowledge about variation
Theory of Knowledge
Psychology of people.

All of these principles find a place in VPP and management at Fluor Hanford. These principles are based upon sound work established 75 years ago by Dr. Walter Shewhart. It is well worthwhile to go back and read the source documents by these authors. Management guru Tom Peters encourages readers to take a risk now and then, establish new systems. For the author, the bringing forth of "old" ideas and ideals is amazingly "new" to most safety professionals. Fluor also has gained benefits and credibility from these results.

Dr. Deming repeatedly stated "there is no knowledge without theory". By applying sound theory and quality tools, Fluor has been successful in elevating its performance. At Hanford, this performance protects lives, property, and the environment; builds productivity and morale; and has enhanced Customer image in the Tri-Cities and Yakima Valley communities Fluor serves. "Experience without theory teaches nothing. In fact, experience cannot even be recorded unless there is some theory, however crude, that leads to a hypothesis and a system by which to catalog observations." (Deming)

The Color Coded Dashboard

Data overload is a common issue. At Fluor Hanford, thousands of charts are made every month. Although no one person receives all of the routine and non-routine charts made each month, this sheer volume of information can be overwhelming. Computers and analysts are capable of flooding managers and safety professionals with reports and data. One potential solution is to color-code the results and roll these results into one scorecard or dashboard, as in Exhibit 3. The red, yellow, and green colors from traffic lights are typically used. Green usually implies "okay," Yellow caution, and Red stop - there is a problem. The U.S. Department of Energy began calling for the use of color coded "dashboard" performance indicator charts in 2001 through its Energy Facility Contractors Group. Traditionally, the chart colors are set by comparing results against a set of thresholds. In the example below, any month with more than ten injuries is red, any month with between five and ten injuries is yellow, and any month with less than five is green. Colors from the various individual charts are then rolled up into a single page overview. The locations of red and yellow colors are intended to provide a quick indication of areas needing attention.

An article recently published by the author in *Professional Safety* used a set of data generated by a computer pseudo-random number generator in order to demonstrate the differences of interpretation of the data (Prevette). Two difference interpretations of the same data from the article are provided here in exhibits 3 and 4.

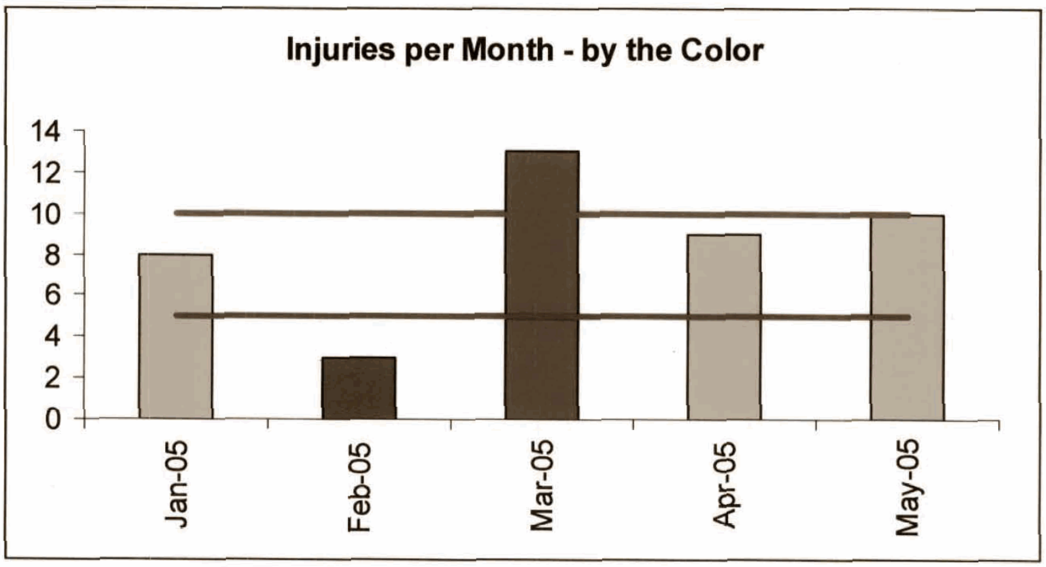

Exhibit 3. This is an example of a typical color coded dashboard chart.

Unfortunately, the intended use of the Exhibit 3 type of chart does not match the outcome of using the charts. A quick summary is provided by the color coding, but the colors may be based upon random fluctuations which will send false alarms, triggering unsuccessful actions. The chart has no criteria for detecting significant change in the data versus these random fluctuations. As in the Red Bead Experiment, the user starts reacting to every change in the data, supposing that there are special causes that may be found as to why the chart was green in February, but went to red in March. The users of the chart become focused upon the past, explaining the inevitable changes in the data from month to month, and fail to become proactive. There is a failure to create and design a better future due to the focus upon past mistakes. A new method is needed.

Appropriate Reaction to Random Noise

The control chart becomes the new method, the new lens for looking at the safety data. A control chart has a center line representing the average of the data, and control limits at 3 standard deviations from the average line. In Exhibit 4, the average line is a heavy black line, the upper control limit (UCL) is red, and the lower control limit (LCL) is green. The example data look like this, when seen through this new lens:

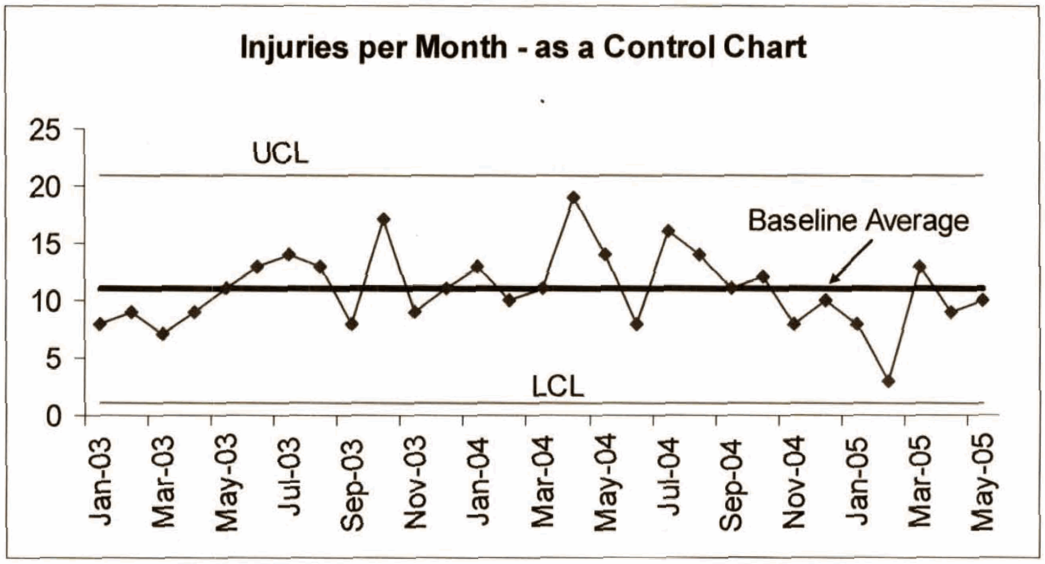

Exhibit 4. The control chart of the injury data provides the intended message.

These data are statistically stable, as shown in Exhibit 4. Nothing was done differently to get the result of 3 in February 2005 as was done to get the result of 16 in July 2004. These results were generated by a computer pseudo-random number generator. Any "signal" in Exhibit 3 was only the result of a random number generator. There must always be a highest value and there must always be a lowest value. Supposing that there must be a signal, that there must be something that can be acted upon in the recent results becomes a source of frustration and represents "numerical illiteracy" (Wheeler).

This new way of looking at data offers a new way of reacting to data. Actually this "new way" was developed by Dr. Walter Shewhart 1930. If the new month's datum is within the control limits, and no other rules for a "trend" found in the list below are triggered, then there is nothing to be gained from further examination of this month's injuries. If the injury rate needs to be improved, then the Red Beads (sources of injuries) need to be removed from the system. Look across all of the months of data for further information. Perhaps back injuries are the leading body part, while strains and sprains are the leading injury types. This implies one should work on actions needed to reduce back injuries overall (not just last month's back injuries). There was an excellent article in ASSE's *The Compass* for Spring 2005 titled "Variation and Acceptable Risk" by F. David Pierce which elaborated on these principles.

A significant issue when using SPC is formalizing a set of rules for declaration of a "signal" or a "trend" in the data. Fluor Hanford has settled upon a set of rules for detecting trends on a control chart which include:

One point outside the control limits
Two out of three points two standard deviations above/below average
Four out of five points one standard deviation above/below average
Seven points in a row all above/below average
Ten out of 11 points in a row all above/below average
Seven points in a row all increasing/decreasing.

Variations on this list do exist. This list came from U.S. Department of Energy direction, and Acheson Duncan's book *Quality Control and Industrial Statistics* (Duncan 434). Dr. Wheeler suggests eight points in a row the same side of the average is at trend. The key is to pick one set of rules that is reasonable, and stick to them. Do not change rules in midstream depending upon the desirability of declaring a "trend".

Presenting Information to Management

A challenge with leading indicators and performance indicators in general lies in the presentation of the indicators to the leaders. Statistical interpretations of the data are necessary, but not sufficient. The leaders require a quick and effective presentation focusing on issues where action will likely lead to improvement.

"Dashboards" and "Balanced Scorecards" have become popular in management culture. Leading and outcome indicators can be integrated with "Dashboard" style indicators, and Fluor Hanford started working with these presentations two years ago. At first the dashboard only consisted of "outcome" indicators. With time, leading indicators were integrated into the package. As of December 2005, there are nine Safety and Health leading indicators, and eight "outcome" indicators in use at Fluor Hanford company total, and seven projects.

A common failing of many dashboards is basing the colors on "lines in the sand". If the result falls between this number and this number, the color is this. This approach completely ignores the issue of random noise versus significant trends. Declaring an indicator "red" due to a random spike in the events will cause people to focus on fixing that month's events, treating them as some form of special, unique event. The efforts will not be focused upon fixing the system that caused the event. Even worse, declaring oneself "green" based upon being below average this month will send the wrong signal to the persons involved in improving performance.

There are two errors possible when trending. The first type of error is reacting to random noise, declaring a trend when one does not exist. The second type of error, failure to detect a trend, is a fear of managers and safety professionals. This fear tends to cause safety professionals to raise a lot of false alarms, causing misapplication of limited resources. Exhibit 5 below provides an overview of these two errors, and proposes a preferred action to be taken when using SPC.

Error	**Typical Behavior**	**Reaction**	**Preferred Action**
Reacting to Ups and Downs (False Alarms)	Comparisons point to point, to average, to last year	Tampering and knee jerk reactions, frustration	When the SPC chart is stable, work on long term history, fix the system
Failure to detect trend	Trends are missed as there are no criteria to separate trend from noise	Molehills grow into mountains	Use SPC to detect trends accurately and in time

Exhibit 5. This table overviews common trending errors, and how SPC can be used.

Using the SPC Results

The lessons from Exhibit 5 are applied at Fluor Hanford as illustrated in Exhibit 6. Exhibit 6 includes the control chart result, stable or trend, as determined by the analyst. The second column contains the decisions needed from the leaders, which puts the control chart in context. The third and fourth columns contain the resulting color, and the recommended leadership actions.

Control Chart Result	**Leadership Decision**	**Color Assignment**	**Leadership Action**
Stable	Level is Acceptable	Green	Stay the Course
	Level is Not Acceptable	Yellow	Improve the System
Trend	Adverse	Red	Take Corrective Action

	Improving	Green	Reinforce – Stay the Course, apply to similar systems

Exhibit 6. This exhibit provides the linkage from SPC results to actions to take to improve performance.

The decision as to whether a stable chart represents acceptable or unacceptable performance is owned by management. Managers must determine if improvement is needed or not. Safety professionals and analysts can help managers in making this decision by gathering benchmark data, performing cost-benefit and risk analyses, and conducting customer interviews and surveys. Managers may choose to execute a policy of continual improvement, and always pick a small number of stable systems for improvement, do the improvement, then move on to others. It is not necessary to make a new decision on each update as to whether or not a stable system is Yellow or Green. This is a one-time decision, which remains in effect until a trend occurs, or other priorities change and force a re-evaluation of this system.

In the traditional dashboard method, the threshold values are established arbitrarily. In the SPC method, there is a decision that must be made - if the process is currently stable, does it need to be improved? The methodology integrates well with Dr. Deming's 14 Points in understanding the variation in the data, and also avoiding numerical targets.

At Fluor, managers and the safety councils review stable systems to determine if improvement is needed. A baseline in effect at some time in the past may be a useful threshold. For example, after starting up a formal safety inspection program it was decided that a higher number of inspections would be worthwhile. The initial baseline average was used to determine colors - Green if a new baseline had been established at a better level than original, White if it had not changed, and Yellow if a new baseline that was lower was established. In other cases, numerical targets had been applied from outside the corporation. Negotiations with the government led to a base goal of 1.0 OSHA recordable cases per 200,000 hours, and a "stretch" goal of 0.75. Thus, any organization stable less than 0.75 was Green, stable between 0.75 and 1.0 was White, and Yellow if greater than 1.0. Note in all cases the baseline average is the basis for the color when there are no trends. Also, the baseline average only changes if a statistically significant change had occurred previously.

Leading Indicators

Much has been written and talked about in the field of Leading Indicators in the past ten years. The dream often stated is to predict future problems and fix them before they occur. Dr. Russ Ackoff points out the fallacy of this notion. One does not simply want to predict the future and attempt to live with it as best practical, but to design and build a desirable future. The difference between building a future and predicting the future is a critical transformation. The belief that one must build "predictive" leading indicators has prevented many corporations from implementing leading indicators. The transformation allows safety professionals to lead with leading indicators.

If one uses leading indicators to measure the activities used to build a better (safer) future, then they can evaluate the effectiveness of the activities, and compare that to the outcomes (OSHA Case Rate, in this instance). Improvement leaders need to formulate the right things to do in order to create the safer and more productive workplace.

The use of a variety of indicators allows the safety professional to integrate across several subject areas. Correlation charts are also made monthly comparing the outcome measures to the leading indicators. Exhibit 7 demonstrates a very strong correlation between the number of "employee concerns" submitted that were safety and health related and the actual OSHA injury rate for the month. This chart provides the lesson that paying attention to employee concerns may help reduce injuries. The intent is to avoid sub-optimizing individual measures within the system by allowing for a cross-cutting look at several related indicators at different organizations.

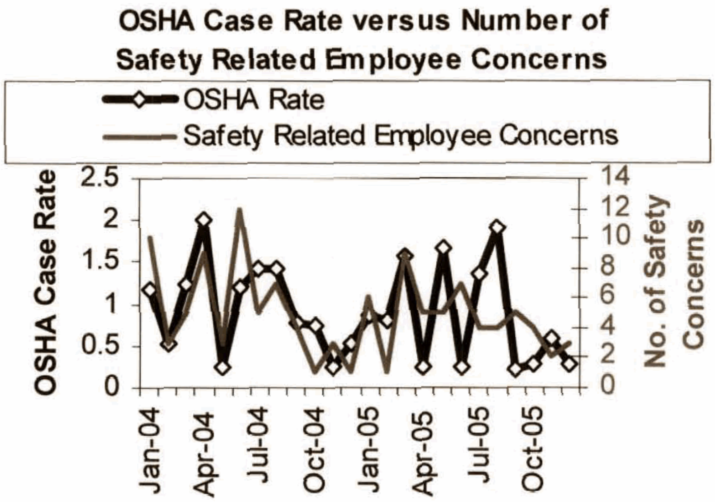

Exhibit 7. This is an example of the correlation charts kept at Fluor Hanford.

A further advantage is seen when the rate of the outcome is very small (such as the 1.5 case rate achieved by Fluor in 2000), it takes a large number of data points to determine if a statistically significant decrease has occurred. If one measures activities that occur at a higher rate, change can be detected faster, and feedback to the employee efforts provided faster.

Fluor Hanford uses the following leading indicators

First Aid Case Rate
Non-nuclear safety Occurrence Reports
Near Misses
Safety Related Employee Concerns
Number of Safety Inspections
Safety Inspection Scores
Hanford General Employee Training Safety Perception Survey
Non-reportable Skin Contaminations.

The Fluorboard

In conjunction with this presentation, an article has been published in the May 2006 *Professional Safety* magazine detailing the theory and methodology used at Fluor Hanford with its dashboard system, the "Fluorboard". Exhibit 8 shows one page of the Fluorboard, the roll up of the Occupational Safety and Health color codes for the company overall, and for its seven major divisions. This was generated in Excel spreadsheet, and is available to safety professionals on an internal web fileserver. Links are set up so that if one clicks on any of the colored cells, a page similar to Exhibit 9 opens.

Fluor Hanford Dashboard: Safety and Health - OS&H

Indicator (with link to definition)	FH Overall	PFP	K Basins	FFTF	WS&D	SW/GWVZ + WSCF	CP D&D & RCC	CS&I
LEADING INJURY INDICATORS	W	W	G	G	W	W	W	W
First Aid Case Rate	Y	W	G	W	Y	Y	R	W
ORPS	Y	W	G	Y	W	W	W	Y
Near Misses	G	G	G	G	G	G	G	G
No. Safety Inspections	G	W	G	G	G	G	G	G
Safety Inspection Scores	G	G	G	G	G	W	G	G
HGET Survey	G	Y	G	G	R	G	W	R
Safety Related Employee Concerns	W	W	W	W	Y	W	G	W
LAGGING INJURY INDICATORS	W	W	G	G	G	W	W	Y
OSHA Case Rate	W	Y	G	G	W	Y	Y	Y
DAFW Case Rate	W	G	G	G	G	G	G	Y
DART Case Rate	G	G	G	G	W	G	W	Y
Severity Rate	G	G	G	G	G	G	G	G

Green = Improving Trend or Superior Performance, White = Acceptable, Yellow = Stable, needs improvement or potential Non-Improving Trend, Red = Unacceptable Level or Non-Improving Trend

Reporting Period - May 2005

Exhibit 8. This is an example of a dashboard cover sheet from early in the program.

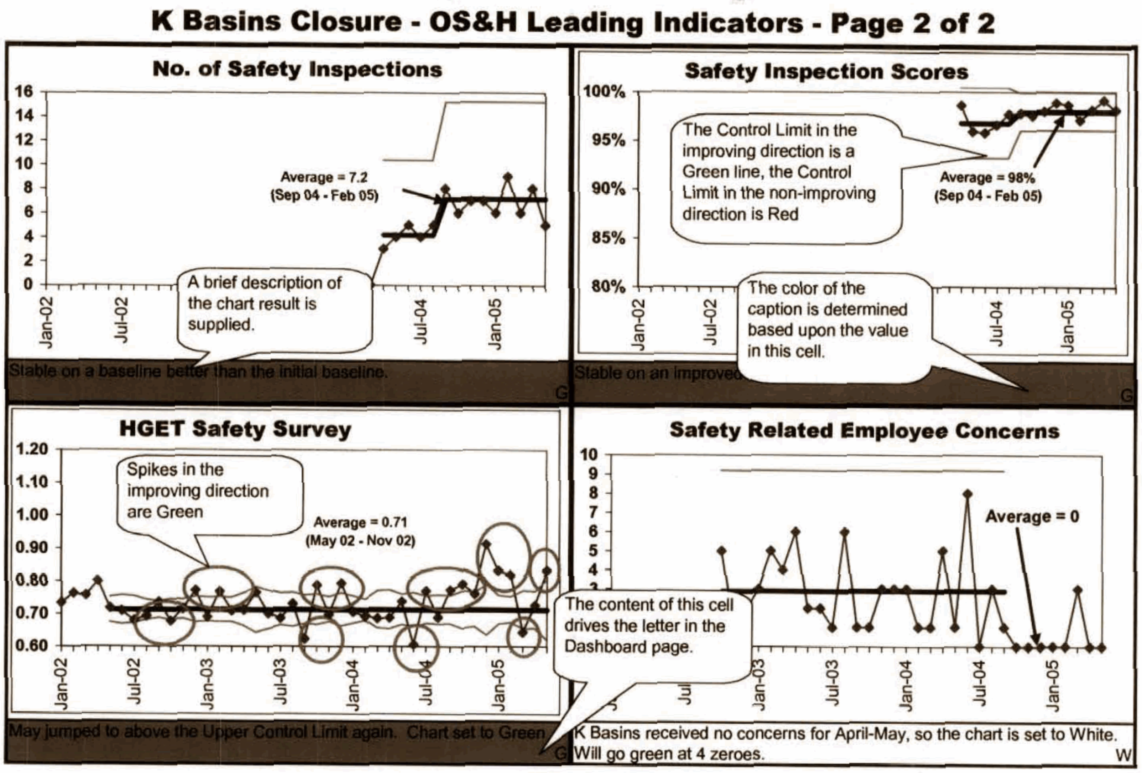

Exhibit 9. Upon clicking on a cell in Exhibit 8, a page of four charts opens.

The Fluorboard has improved communication and information about safety performance between management, the safety professionals, and the workers. The color coding allows for a quick "executive summary" for the managers. The detailed trend charts are immediately available within the same software package. In addition, further text reports and bar charts (Pareto charts) are provided to the projects and facilities within the company. These provide information on causes of injuries, occupations of the workers injured, body parts and types of injuries. The leading indicators are also provided with greater detail, such as information on items found during safety inspections and trends on individual questions within the employee safety survey. This provides the information needed to assist the safety professionals in assisting the workforce.

Conclusion

The SPC based dashboard has been very successful at Fluor Hanford, and the effort to apply it across the Fluor corporation has begun. This methodology combines the best technical features of Statistical Process Control with the best presentation features of Color Coded Dashboards. Safety professionals and managers are now able to quickly make rational use of their data, and make informed decisions. The effect of these decisions will also be determined in a credible, rigorous manner through the SPC trend rules.

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